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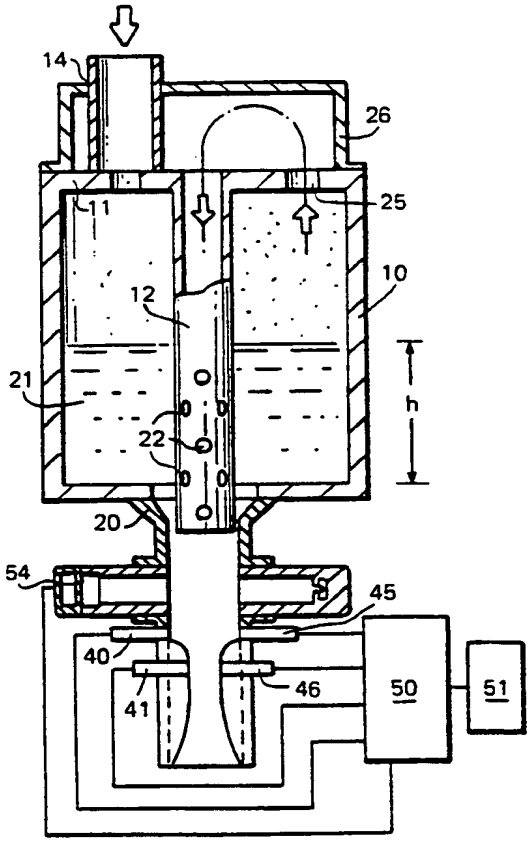
(54) Title: MULTIPHASE PROCESS MIXING AND MEASURING SYSTEM

(57) Abstract

A liquid is supplied to a vessel (10) to form a pool (21) from which it discharges through a venturi. A supply pipe or pipes (12, 30) convey other liquids and/or gases from separate sources or from above the liquid pool into the venturi for mixing with the liquid. The supply pipes can extend through the pool and be perforated (22) to tend to maintain the level of the pool. Associated with the venturi are pressure sensors (40, 41) for measuring flow and a densiometer (52) permitting mass flow rate measurement of gas and liquid phases. The apparatus can be incorporated in a cartridge (60) for reception in a receptacle (61) at a subsea installation.



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MULTIPHASE PROCESS MIXING AND MEASURING SYSTEM

The invention relates to a multiphase process mixing and measuring system, more specifically, to a system by which two or more fluid materials, that is, liquids, gases or vapours, are mixed and by which the mixed materials can be metered if desired.

According to the invention, there is provided a method of and an apparatus for mixing at least one fluid with a liquid, in which the liquid flows from a pool through a venturi passage, and the fluid to be mixed with it is introduced into the liquid flow for mixing in the venturi. Mixing or homogenizing is thus effected in that the fluid, which may be a gas or vapour, or a second liquid, is drawn into the venturi passage by the flow through it of the first-mentioned liquid. It may be desired to mix with the liquid more than one fluid, and the inlet pipe can then be constituted by two or more concentric pipes, of which the inner pipe and the space or spaces between it and the or each outer pipe supply a fluid into the venturi.

The invention can thus provide apparatus comprising a vessel or chamber into which a liquid from a first source can be fed to form a pool of liquid, the chamber having a discharge passage having a restriction to form a venturi, into which projects the free end of an inlet pipe for feeding into the venturi a fluid from a second source to be mixed with the liquid.

The invention can be embodied in apparatus for mixing or homogenizing a multi-phase fluid flow. The chamber can thus be a closed chamber, with means

communicating between the inlet pipe and the upper region of the chamber, that is, the region above the pool formed by the liquid phase of the multi-phase fluid flow, the upper region constituting the second source and the pool constituting the first. The introduction into the homogenized multiphase flow of one or more fluid additives can again be effected by use of concentric inlet pipes. The flow into the discharge passage can be induced by gravity, the outlet from the chamber being then located in its floor. An apparatus in accordance with the invention can nevertheless be designed to be located directly upstream of a suitable pump or booster.

Preferably, the apparatus incorporates means tending to maintain a level of the liquid in the vessel or chamber. The invention can accordingly provide that the or each inlet pipe conveying fluid into the venturi extends through the pool of the liquid in the chamber and is provided with apertures or perforations. The amount of the liquid drawn off from the liquid pool thus increases as a function of the increase of the liquid level, as more of the perforations are submerged.

An apparatus embodying the invention can moreover be conveniently associated with flow measuring means. Flow meter arrangements operating on the pressure drop ensuing when a fluid flow through a venturi can be integrated with the apparatus by locating pressure sensors at the discharge venturi. By inclusion of a densiometer mass flow rates of a homogenized multi-phase fluid flow can be reliably determined.

The apparatus of the invention can be applied to the homogenization and/or measurement of a mixture of oil, water and gas and can be embodied in a form

suitable for subsea use. The invention thus also provides a flowmeter cartridge, which can incorporate a choke, arranged for subsea installation, as by installation in a barrel receptacle connected to a X'mas tree.

It will be evident that the invention has a variety of applications particularly in the oil industry, where it can be applied to chemical injection and blending as well as to on-shore and off-shore handling of crude oil. In its aspect as a homogenizing apparatus, it is applicable in particular to the mixing or homogenization of mixtures of gas and oil extracted from onshore or subsea wells. The fluid extracted from such wells can vary substantially as regards its gas and liquid components. It may comprise slugs of substantially unmixed liquid separated by primarily gaseous portions, as well as portions that are more or less homogeneous. This inconsistency of the nature of the extracted material makes it difficult to handle, in particular by pumping equipment.

The invention is further described below, by way of example, with reference to the accompanying drawings, in which:

Figures 1, 2 and 3 are sectional side views of first, second and third forms of mixing or homogenizing apparatus in accordance with the invention;

Figure 4 is a part-sectional side view of a receptacle of a subsea installation having received therein a cartridge incorporating an apparatus as illustrated in Figure 2;

Figure 5 is a side view of the subsea installation in which the receptacle is mounted; and

Figure 6 is a plan view on a smaller scale of the subsea installation.

The mixer apparatus of Figure 1 comprises an

upright cylindrical container 10, the upper end wall 11, of which is provided with a central aperture through which a pipe 12 extends along the container axis. Adjacent the pipe 12, an upright inlet duct 14 communicates with the container interior through a second aperture in the upper end wall 11 offset from the axis. The lower end wall 16 of the container has a central outlet 17 by which the container communicates with a hollow discharge fitting 20 of which the interior is shaped to function as a venturi. The central pipe 12 extends, with spacing, through the outlet 17, with its open lower end just within the fitting 20.

A liquid introduced into the container through the inlet duct 14 at an appropriate flow rate forms a pool 21 from which the liquid flows under gravity through the outlet 17 and the discharge fitting 20. A second liquid or a gas available by way of the pipe 12 will be drawn by the venturi along the pipe and so effectively mixed with the liquid entering through the duct 14. The pipe 12 is provided with apertures or perforations 22 over at least its lower region so that the liquid in the pool 21 can enter the venturi by way of the pipe as well as through the outlet 17. A degree of regulation of the level of the pool 21 is thus obtained, in that more of the perforations 22 become available for the liquid to discharge as the level of the pool rises.

The apparatus of Figure 1 is thus intended for mixing together a liquid from a first external source with another liquid or a gas from a second, different, external source. The apparatus has a variety of applications as for chemical injection or the drip feed of additives to a liquid.

The form of apparatus shown in Figure 2 is arranged for mixing together liquid and gaseous phases

occurring in a single incoming fluid supply, and thus functions as a homogenizer. In the following description of the apparatus of Figures 2 and 3, reference numerals already used in Figure 1 are used again for like or similar parts.

The apparatus of Figure 2 differs from that of Figure 1 in that the fluid source for the central pipe 12 is the upper part of the container interior. For this purpose, the central pipe 12 does not extend upwardly beyond the upper end wall 11, which is provided with a second axially offset aperture 25. A sub-container 26, in the form of a cylinder of lesser axial length and diameter than the main container, and through which the inlet duct 14 extends, is mounted on the upper end wall 11 and both the aperture 25 and the pipe 12 communicate with it.

The liquid phase of a multi-phase fluid flow entering the container 10 by way of the inlet duct 14 tends to separate under gravity from the gaseous phase and forms the pool 21 in the lower part of the container. The gaseous phase occupies the upper part of the container, above the surface of the liquid pool. The liquid phase is withdrawn from the pool 21 through the discharge fitting 20 under gravity and the effect of the venturi is to draw gas from the upper part of the container through the aperture 25, the sub-container 26 and the central pipe 12 into the venturi. The liquid phase is consequently mixed with the liquid phase, so that a homogenized or substantially homogenized fluid is obtained in the discharge fitting 20. If the multi-phase fluid flow entering the container is already homogenous or approximately so, then the mixture will be discharged through the discharge fitting by way of both the opening 17 and the pipe 12.

The void fraction α of the fluid discharged from the container 10 depends on the dimensions of the venturi, and can be made independent of the total flow rate Q^T, the liquid level h in the container, and the absolute pressure ρ.

Assuming that both some liquid and some gas are present in the container 10, the total pressure drop for the gas and for the liquid phases flowing through it will be equal, and the void fraction from the container can be obtained from the resulting equation as follows:

$$\frac{\rho_L}{2}(1-\alpha)^2 \cdot Q_T^2 \left[\frac{(1+\xi_L)}{A_L^2} - \frac{1}{A_T^2} - \frac{2 \cdot g \cdot h}{(1-\alpha)^2 \cdot Q_T^2}\right] = \frac{\rho_G}{2}\alpha^2 \cdot Q_T^2 \left[\frac{(1+\xi_G)}{A_G^2} - \frac{1}{A_T^2}\right]$$

where:

A_T - the cross-sectional area of the container,

A_L - the cross-sectional area of the liquid in the venturi,

A_G - the cross-sectional area of the gas in the venturi,

ξ_L - the total liquid loss coefficient,

ξ_G - the total gas loss coefficient,

ρ_L - the liquid density,

ρ_G - the gas density, and

g - gravity.

During steady flow conditions, the average void fraction drawn from the container will equal the average void fraction entering it. To ensure that both liquid and gas are always present in the container, it is convenient to decrease the gas fraction drawn off as the liquid level increases, and vice versa, and this is achieved by the perforations 22 in the central pipe 12.

The perforated pipe portion 22 thus acts as an integral regulator allowing a variation in the void fraction. Any desired mixing unit characteristic can be obtained by appropriate choice of dimensions of the venturi and the perforations 25 in the pipe portion 22.

In some applications of the apparatus of Figure 2, it may be desired to introduce a fluid additive into the homogenized flow discharged from the fitting 210 and this can be readily achieved by means of the form of apparatus shown in Figure 3.

The apparatus of Figure 3 resembles that of Figure 2 but with the addition of a tube 30 received co-axially with spacing, within the tube 12. The inner tube 30 extends to the lower end of the tube 12 and communicates at its upper end with a source of the desired liquid or gaseous additive, which is drawn into the venturi fitting together with the liquid phase from the pool 21 and the gaseous phase above it, so as to be effectively mixed together with these phases. An inner tube such as the tube 30 could be added to the apparatus of the other Figures where it is desired to mix more than one fluid with the liquid supplied through the inlet duct 14.

In some applications of the forms of apparatus illustrated in Figures 1, 2 and 3, it is desirable to provide a measure of the fluid flow passing through the apparatus and the apparatus can be connected to a downstream flowmeter. However, as each form of the apparatus includes a venturi, flow measuring means of the kind dependent on the pressure drop occurring in a venturi can readily be integrated with the mixer apparatus.

Thus as schematically shown in Figure 2 only, although applicable also to the apparatus of Figure 1 and Figure 3, the fitting 20 mounts axially spaced

upstream and downstream pressure probes or gauges 40 and 41 which provide output signals, which represent sensed fluid pressure. The upstream gauge 40 is located at the entry to the Venturi throat and the gauge 41 is located at the throat itself. The gauge output signals are supplied to a processing equipment 44. Spaced upstream and downstream temperature sensors 45 and 46 are also carried by the fitting 20, at respective axial locations corresponding to those of the pressure gauges 40 and 41. Output signals representing sensed temperature are supplied from the sensors 45 and 46 to the processing equipment 50. The output signals from the temperature sensors 45 and 46 are employed in the processing equipment 50, which provides outputs to a display and/or a recording device 51, to compensate for variations in density due to temperature changes.

The mixture flowing through the fitting 20 comprises both gaseous and liquid phases and the mass flow rates of the separate phases can be computed by the processing equipment 50 by the supply to it of output signals from a densiometer 52 which can be of any suitable kind for example a y-ray or x-ray densiometer. The homogenized nature of the fluid flow in the fitting 20 ensures an accurate result.

Although reference has been made to fluid flow through the apparatus of Figures 1, 2 and 3 under gravity, the flow can be boosted or induced by a downstream booster 31 or pump, schematically indicated Figure 3 only, but applicable also to the apparatus of Figure 1 or Figure 2, mounted below the discharge or venturi fitting 20.

The present invention has application particularly but not exclusively in the oil industry. For example, crude oil comprising a mixture of gas, oil and water

can be fed through the apparatus of Figure 2. For use in subsea installation, the apparatus can be incorporated as shown in Figure 4 into a cartridge 60 for reception in an upright open-topped receptacle 61 located at the installation. The receptacle 61 can be mounted as shown in Figures 5 and 6 on a frame for a satellite production X'mas tree 63, conveniently on the opposite side of the X'mas tree from a control module 62, to assist in balancing the frame.

The cartridge 60 has upper, intermediate and lower sealing means 64,65 & 66 of equal diameter for sealing to a lower portion of the receptacle 61, of uniform inner cross-section. The sealing means are activated by hydraulic pressure after entry of the cartridge 61 into the receptacle. The space between the upper and intermediate sealing means 64 and 65 defines a sealed entrance chamber into which the crude oil which is carried by piping 69 through an aperture in the receptacle wall. From the entrance chamber, the crude oil enters the container 10 of the mixing or homogenizing apparatus through which it flows. The lower sealing means 66 defines the lower end of a discharge chamber into which the mixed and measured crude oil flow enters from the lower end of the fitting 20 of the apparatus, and from which it is discharged outwardly of the receptacle through an aperture in the receptacle wall into piping 70.

Electrical and hydraulic power connection to the cartridge 60 is effected through coupling arrangements comprising an aperture formed in the base wall of the receptacle 61 and a connector plug 72 protruding from the lower end of the cartridge and which is introduced into the aperture by a stab-in operation during installation of the cartridge. Above the upper sealing means 64, the cartridge 60 comprises a connector 74, by

which it is mechanically locked down within an upper portion of the receptacle of greater diameter than the lower portion, and a running neck 75 by which it is lowered into the receptacle during installation and can be lifted if retrieval is necessary, by means of a dedicated running tool.

Electrical and hydraulic connections with the cartridge 61 are made by way of the connector plug 72 and an electric/hydraulic signal integrator 76 located below the lowest sealing means 66. The cartridge can if desired incorporate a choke 80 which may be located upstream of the flowmeter apparatus as shown or downstream of it, and to which connections extend from the integrator 76, as well as to the flowmeter apparatus, unless the choke comprises a mechanically operated choke valve. Control and information signals are routed through the plug 72 and the integrator 76 between the cartridge and the X'mas tree control module 62 and through an umbilical 81 for the installation to a control centre.

The flowmeter cartridge 60 and the receptacle 61 are mounted downstream of the X'mas tree 63 wing valve to which it is connected by means of a hard piped flange connection, so that the crude oil flows continuously from the tree through a master valve and the wing valve to the cartridge and outwardly to transport piping by way of a flowbase connector.

It will be understood that the invention can be embodied in a variety of ways other than as specifically described.

CLAIMS

1. An apparatus for mixing or homogenizing a liquid and at least one liquid or gaseous fluid, the apparatus comprising a vessel (10) having an inlet (14) for the liquid and an outlet (17) for liquid in a pool in the vessel, a duct (20) including a venturi communicating with the outlet, and passage means (12;12,25,26;12,30) for supplying the at least one fluid to the duct for mixing with the liquid in the venturi.

2. An apparatus as claimed in claim 1 having flowmetering means for measuring flow through the venturi duct comprising pressure sensors (40,41) located respectively at the entry to the venturi throat and at the throat, processing means (50) for processing the sensor outputs, and display and/or recording means (51) responsive to the processing means output.

3. An apparatus as claimed in claim 2 wherein the flowmetering means comprises sensors (45,46) responsive to fluid temperature at the pressure sensors (40,41) and the processing means (50) employs the temperature sensor outputs to compensate for temperature dependent density changes.

4. An apparatus as claimed in claim 2 or 3 wherein the flowmetering means includes a densiometer (52) and the processing means (50) is responsive to the outputs of the pressure sensors (40,41) and the densiometer to compute the mass flow rates of gaseous and liquid phases in the venturi duct (20).

5. An apparatus as claimed in claim 1, 2, 3 or 4 wherein the passage means (12,25,26) communicates the interior of the vessel (10) above the liquid pool and

the duct (20).

6. An apparatus as claimed in any preceding claim wherein the passage means (12;30) supplies at least one fluid to the duct (20) from an external source or respective external sources.

7. An apparatus as claimed in claim 6 wherein the passage means comprises two concentric tubes (12,30) communicating with respective fluid sources.

8. An apparatus as claimed in any preceding claim wherein the passage means comprises at least one supply pipe (12) extending through the liquid pool (21) and having perforations or apertures (22) at positions corresponding to different depths within the pool for entry into the supply pipe of an amount of the liquid dependent on the level of the pool so as to tend to retain both liquid and gas within the vessel (10).

9. An apparatus as claimed in any preceding claim wherein the duct (20) communicates downstream with the inlet of a booster or a suction pump (31).

10. A subsea installation incorporating an apparatus as claimed in any preceding claim for mixing or homogenizing crude oil and gas.

11. A subsea installation as claimed in claim 10 wherein the apparatus is incorporated in a cartridge (60) received in a receptacle (61) of the installation into which the cartridge can be placed from surface equipment and from which it can be retrieved.

12. A subsea installation as claimed in claim 11 having seating means (64,65,66) operative between the cartridge (60) and the receptacle (61), the sealing means defining an entrance chamber and a discharge chamber communicating respectively with the inlet (14) and the duct (20) of the apparatus.

13. A subsea installation as claimed in claim 11 or 12 comprising means (74) for locking the cartridge

(60) to the receptacle (61) after reception therein, and means for activating the sealing means (64,65,66) by hydraulic pressure.

14. A subsea installation as claimed in claim 11, 12 or 13 having electrical and/or hydraulic connection means (72) between the cartridge (60) and the subsea installation, the connection means being arranged to be effective as a consequence of stab-in installation of the cartridge in the receptacle (61).

15. A method of mixing or homogenizing a liquid and at least one liquid or gaseous fluid, the method comprising forming a pool of the liquid, establishing a flow of the liquid from the pool through a venturi, and introducing the at least one fluid into the liquid flow for mixing with the liquid in the venturi.

16. A method as claimed in claim 15 comprising the step of measuring fluid flow through the venturi by sensing pressure change thereat.

17. A method as claimed in claim 16 comprising compensating the fluid flow measurement by sensing temperature change at the venturi.

18. A method as claimed in claim 16 or 17 comprising determining mass flow rates of gas and liquid phases in the venturi by density measurement thereat.

19. A method as claimed in any one of claims 15, 16, 17 or 18 comprising forming the pool from a mixture of the liquid and the fluid, and drawing the fluid introduced into the liquid flow from above the pool.

20. A method as claimed in any one of claims 15-19 comprising introducing the or each fluid into the liquid flow from an external fluid source.

21. A method as claimed in any one of claims 15-20 comprising co-ordinating the flow of liquid into and out of the pool so as to maintain the level of the

liquid pool.

22. A method as claimed in claim 21 comprising drawing gaseous fluid from above the liquid pool together with liquid from the pool in relative amounts dependent on the depth of the liquid pool.

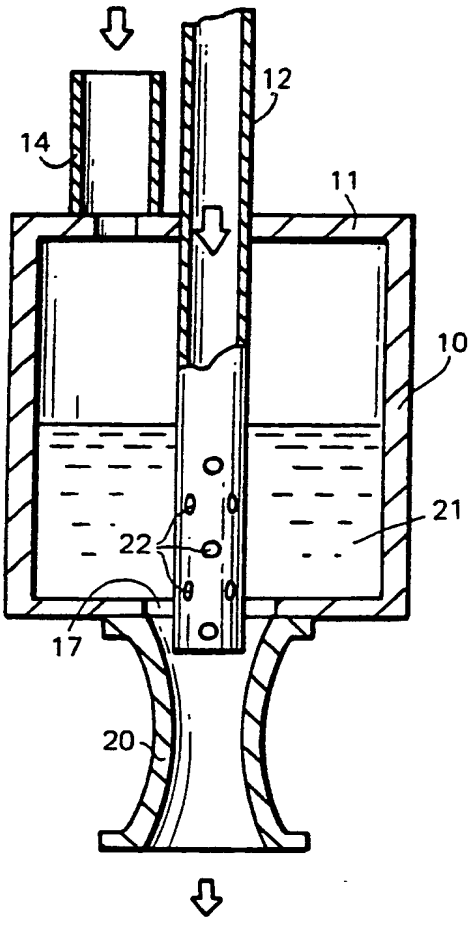

FIG.1

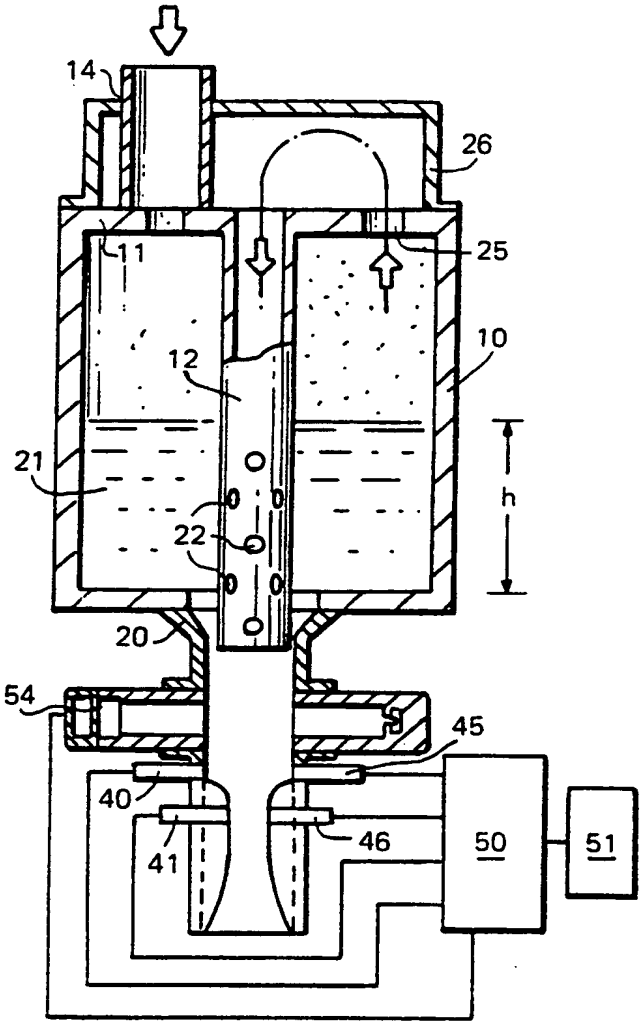

FIG.2

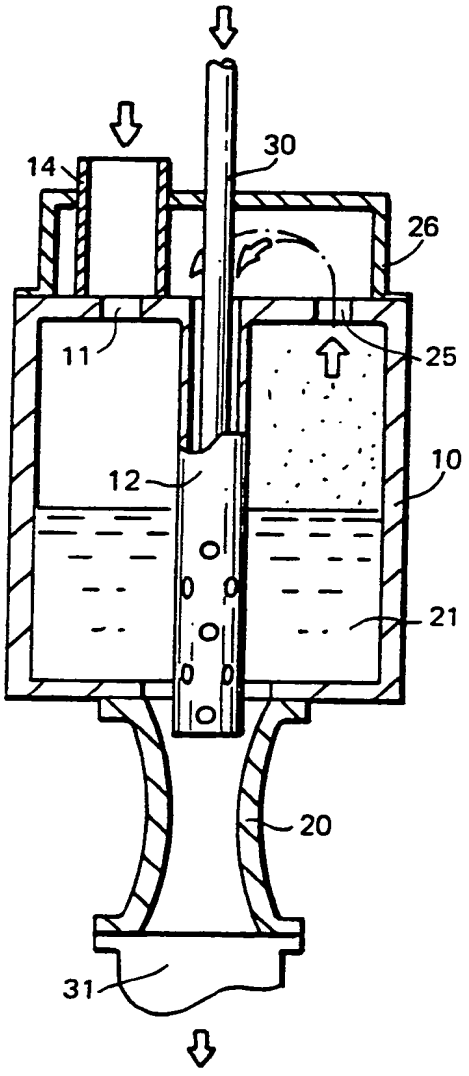

FIG.3

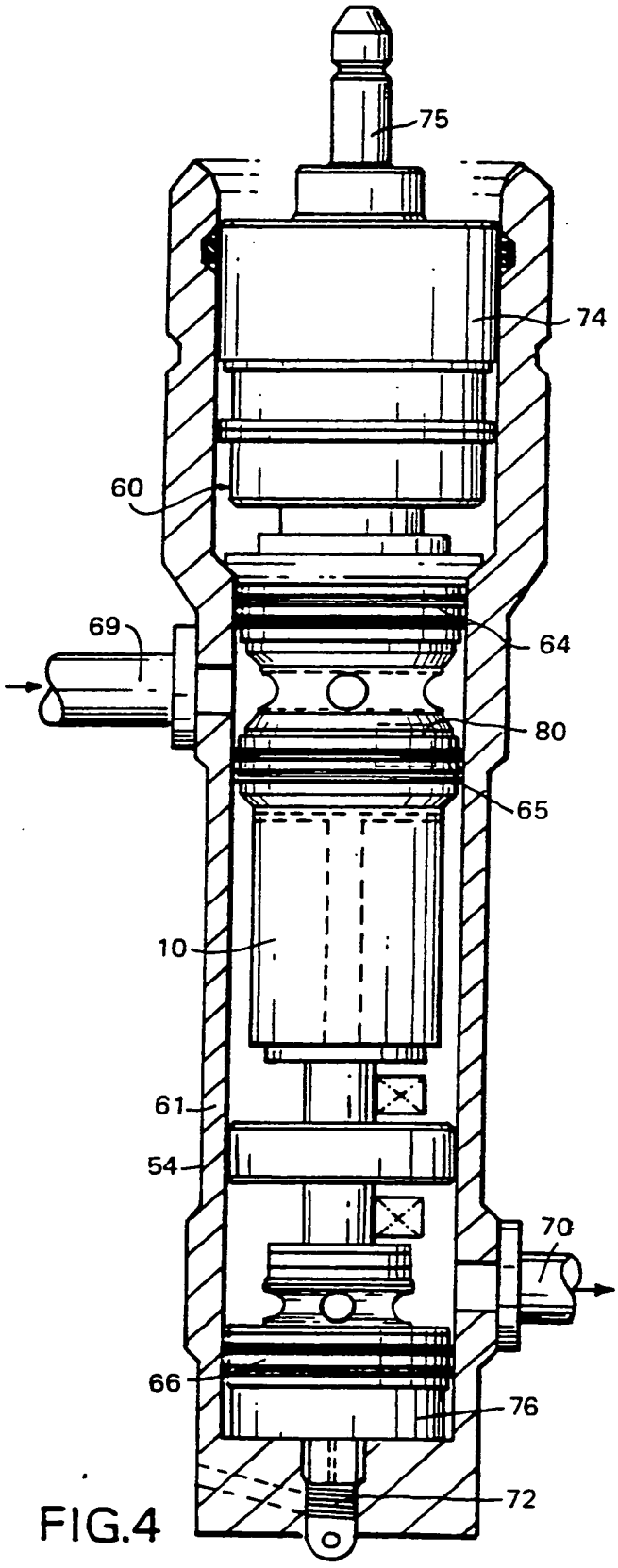

FIG.4

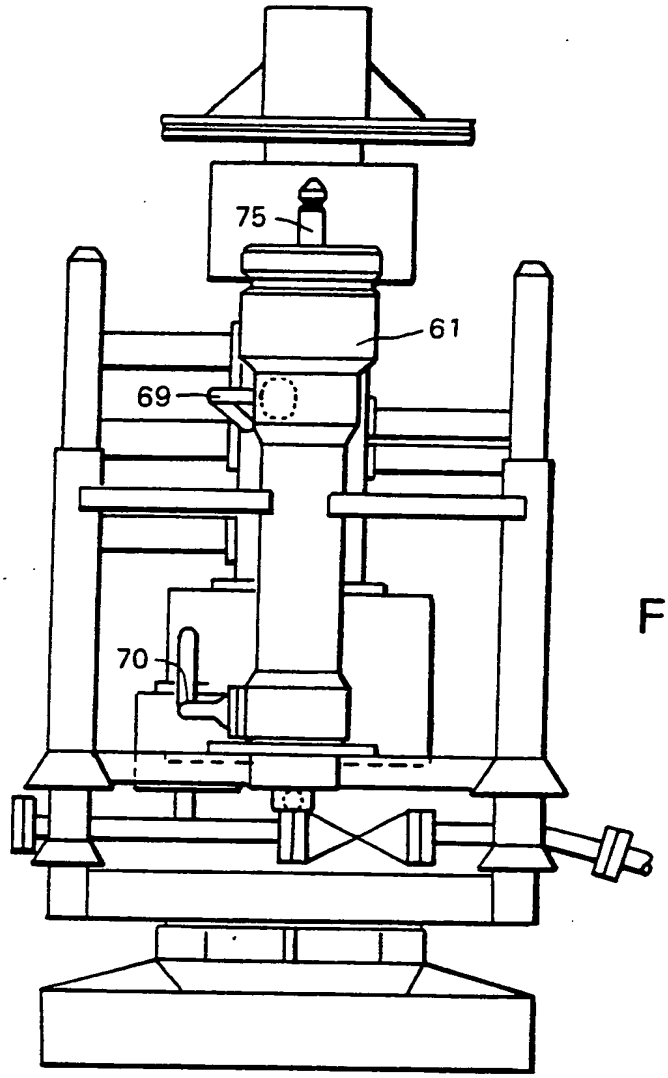

FIG.5

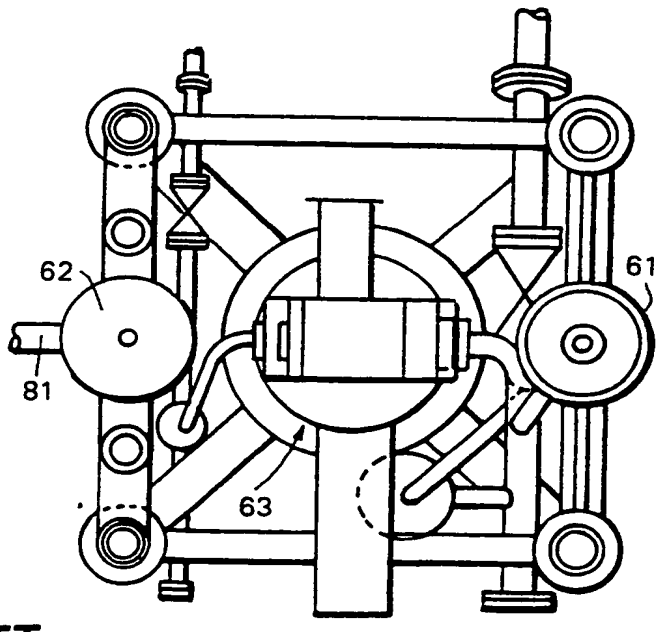

FIG.6

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 90/00701

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 G05D11/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	G05D

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
A	US,A,3556141 (HOBART M. HIND) 19 January 1971 see the whole document	1
A	GB,A,2157854 (KABUSHI KAISHA KOKUSAI TECHNICALS) 30 October 1985 see abstract see page 1, lines 5 - 38; figure 3	2, 3
A	US,A,2670002 (DAVID B. BELL) 23 February 1954 see column 1, lines 1 - 48; figures 1-5	1
A	US,A,2234561 (ARTHUR E. KITTREDGE) 11 March 41 see page 1, left-hand column, lines 1 - 54; figure 1	1
A	US,A,3405907 (LUTZ T. KAYSER) 15 October 1968 see abstract; figure 1	1

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
06 AUGUST 1990	28. 08. 90
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	SCHOBERT D.A.V.

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	US,A,2219763 (ROBERT H. CARTIER) 29 October 1940 see the whole document	1
A	EP,A,9520 (FOLLAND ENERTEC LTD) 16 April 1980 see abstract; claims 1-15; figure 2	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

GB 9000701
SA 36573

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-3556141	19-01-71	None	
GB-A-2157854	30-10-85	JP-A- 60226620	11-11-85
		JP-A- 60258291	20-12-85
		DE-A,C 3514518	24-10-85
		US-A- 4614438	30-09-86
US-A-2670002		None	
US-A-2234561		None	
US-A-3405907		None	
US-A-2219763		None	
EP-A-9520	16-04-80	None	